# Data Exchange between CAD/CAE/CAM Systems

Description of product or product definition data:

- Engineering Drawings (Manual or Electronic):
  - Vector data for lines (solid lines, dotted lines, centre lines, dimension lines, and extension lines)
  - Annotation data for the dimension values, notes, and symbols in the drawing.
- CAD Systems:
  - A solid model representation with some associated annotation data.

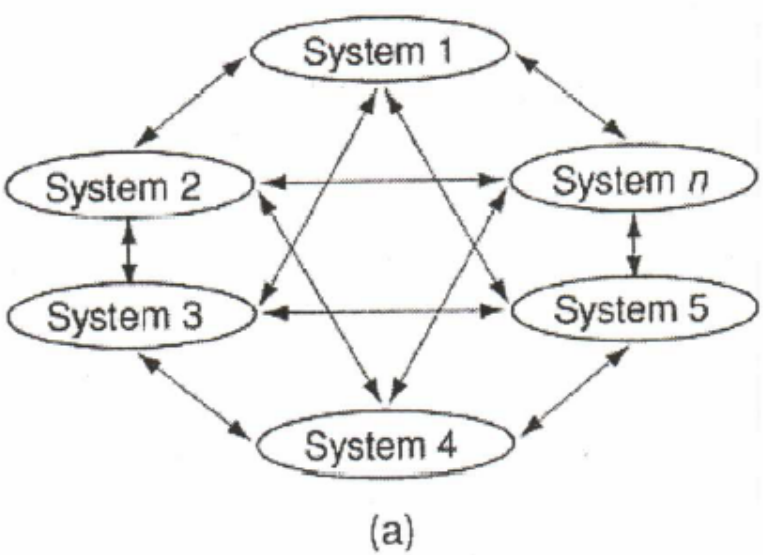
# Driving Forces for CAD/CAM Data Exchange

- Fundamental incompatibilities among entity representations
- Complexity of CAD/CAM systems
- The varying requirements of users
- Restrictions on access to proprietary database information
- Rapid pace of technological change

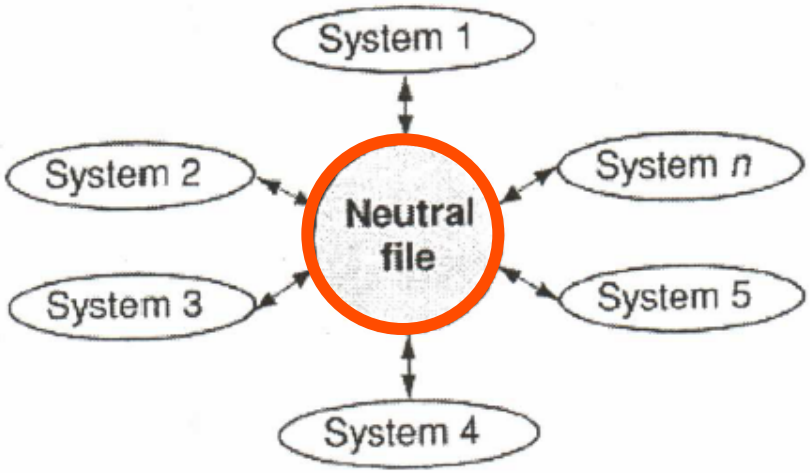
# Requirements for the Exchange

- Shape data: both geometric and topological information, part or form features. Fonts, color, annotation are considered part of the geometric information.
- Non-shape data: graphics data such as shaded images, and model global data as measuring units of the database and the resolution of storing the database numerical values.
- Design data: information that designers generate from geometric models for analysis purposes. Mass property and finite element mesh data belong to this type of data.
- Manufacturing data: information as tooling, NC tool paths, tolerancing, process planning, tool design, and bill of materials (BOM).

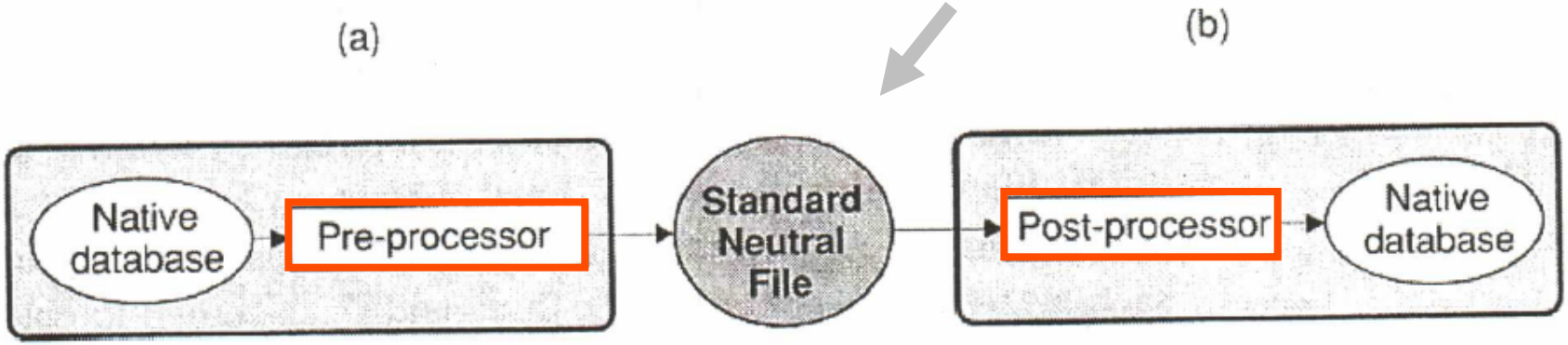
# Exchange Methods




(a)




(b)




Pro/E, SolidWorks, AutoCAD, etc.

IEGS, STEP, etc.

Pro/E, SolidWorks, AutoCAD, etc.

Standard neutral data formats:

- Initial Graphics Exchange Specification (**IGES**) - the most popular format of the neutral file, supported by all CAD/CAE/CAM systems and defined by the international standard organization (ISO).
- Drawing Interchange Format (**DXF**) - a format originated by AutoDesk and used mainly for the exchange of drawing data.
- Standard for The Exchange of Product Model Data (**STEP**) - the standard data format used to store all the data relevant to the entire life cycle of a product, including design, analysis, manufacturing, quality assurance, testing, and maintenance, in addition to the simple product definition data. The data format was also called **PDES** (Product Design Exchange Specification) at the early stage of its development in North America.

A number of other neutral data formats for CAD/CAE/CAM systems were used in the past. These include PHIGS, NAPLPS and GKS.

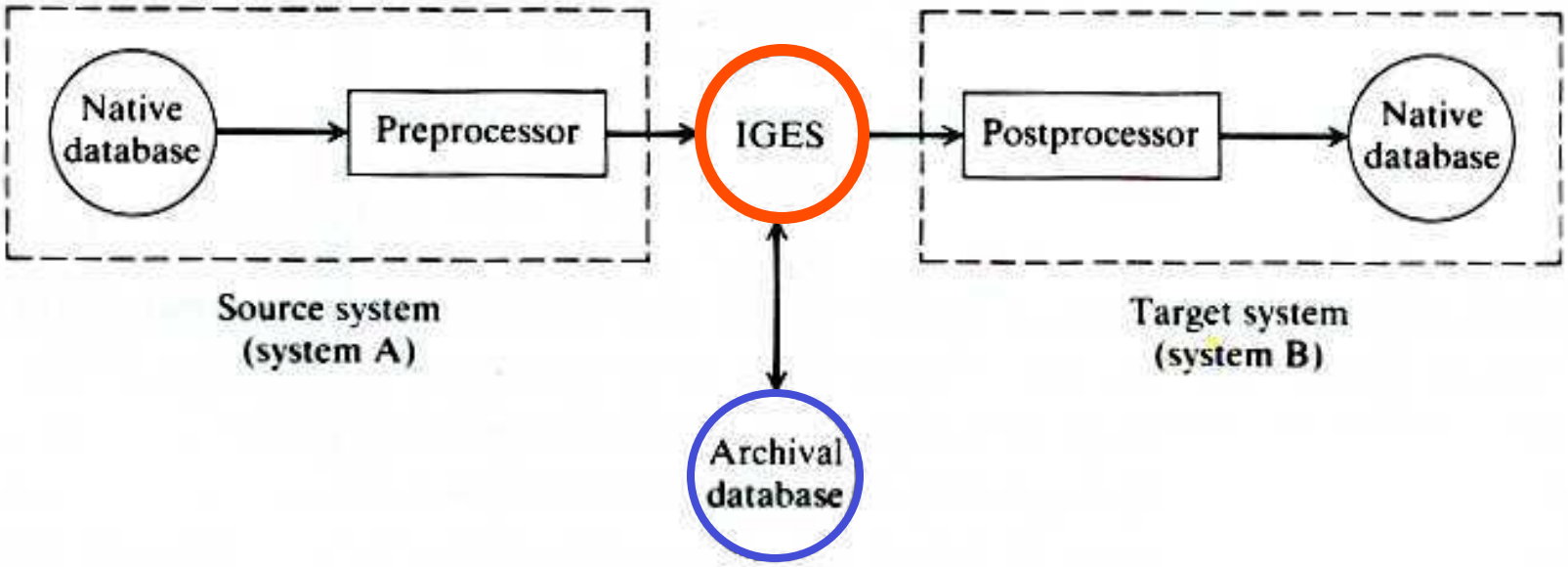
Currently, CAD systems, which used to support IGES format, are moving toward the use of STEP.

# IGES (Initial Graphics Exchange Specification)

- first developed by National Institute of Standards and Technology (NIST) in 1980.
- then adopted by the American National Standards Institute (ANSI) in the same year.
- exchanges primarily shape (both geometric and topological) and non-shape data, which is referred as CAD-to-CAD exchange

# IGES (Initial Graphics Exchange Specification)

- codes a superset of common entities of all CAD/CAM systems to facilitate the translation between various systems



# Development of IGES

As a result of this effort, IGES, version 1.0, was published in January 1980. It became an American National Standards Institute (ANSI) standard in September 1981. IGES was the first standard exchange format developed to address the need to communicate product definition data between different CAD/CAM/CAE systems. Additional capabilities were added later.

- IGES version 1.0 - mainly addresses the exchange of CAD drawings.
- IGES version 2.0 - supports the exchange of finite-element data and printed circuit-board data

2D

- IGES version 3.0 - enhances the capabilities of user-defined Macros that are essential to exchange the standard part libraries.
- IGES version 4.0 - supports the CSG tree of a solid,
- IGES version 5.0 - handles the B-rep data of solids.

3D

# IGES Format

An IGES file is composed of six sections in the following order. A record is a line comprising 80 characters.

1. Flag (optional),
2. Start,
3. Global,
4. Directory Entry (DE),
5. Parameter Data (PD), and
6. Terminate

background

content

data

Originally based on FORTRAN Format
- ASCII and Binary
- 80 Characters per Line
- Data by Field

# In IGES File

**The Flag section** is used only with the compressed ASCII and binary formats. IGES data in a file can be represented in two formats: ASCII and binary. The ASCII format comprises two types: a fixed 80-character record length and a compressed form. The compressed form is simply an ASCII file compressed by eliminating spaces from the records.

**The Start section** provides a human-readable description of the file, such as the sending system that generated the original data, the pre-processor, and the product being described.

**The Global section** includes information describing the pre-processor and information needed by the post-processor to interpret the file. Some of the items specified in this section are

- the characters used as delimiters between individual entries and between records
- the name of the IGES file itself,
- the number of significant digits in the representation of integers and floating point numbers on the sending system,
- the date and time of the file generation,
- the model space scale,
- the model units,
- the minimum resolution and maximum coordinate values, and
- the name of the author of the file and organization.

# In IGES File

**The Directory Entry section** is a list of all the entities together with certain of their attributes. In an IGES file, all product definition data are expressed as a list of predefined entities - the geometric entities such as lines, curves, planes, and surfaces and the annotation entities such as notes and dimension values. Each entity is assigned a specific entity type number. The entry for each entity occupies two 80-character records that are divided into a total of twenty 8-character fields. The first and the eleventh (beginning of the second record of any given entity) fields contain the entity type number. The second field contains a pointer to the record in the Parameter Data section where the actual data defining the entity are stored. This pointer is simply the sequence number of the relevant record in the PD section. The remaining fields are used to store the attributes, such as line fonts, layer number, transformation matrix, line weight, and color.

**The Parameter Data section** contains the actual data defining each entity listed in the Data Entry section. For example, a straight-line, entity is defined by the six coordinates of its two end points. While each entity always has two records in the DE section, the number of records needed for each entity in the PD section varies from one entity to another and depends on the amount of necessary data. Parameter data are placed in free format in columns 1 through 64. The parameter delimiter specified in the Global section is used to separate parameters, and the record delimiter - also specified in the Global section - is used to terminate the list of parameters. Usually, commas are used as parameter delimiters, and semicolons are used as record delimiters. Columns 66 through 72 in all PD records contain the pointer to point back to the corresponding entity in the DE section. Note that this pointer has the sequence number of the first of the two records of each entity in the DE section. Columns 74 through 80 contain the sequence number of its own record. The Terminate section contains a single record that specifies the number of records in each of the four preceding sections for checking purposes.

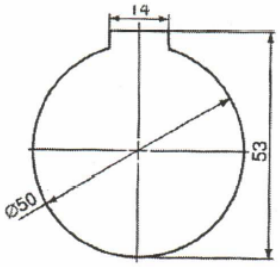
# Example IGES File

Global Section

```
IGES file generated from an AutoCAD drawing by the IGES                 S0000001
translator from Autodesk, Inc., translator version IGESOUT-3.04.        S0000002
,,10HB:WKEYHOLE,14HB:WKEYHOLE.IGS,27HAutoCAD-12_c2 International,12HIGESGD000001
OUT-3.04,32,38,6,99,15,10HB:WKEYHOLE,1.0,1,4HINCH,32767,3.2767D1,13H930TGD000002
06.211545,5.0D-9,5.0,13HShin Dong Koo,12H GoldStar G1,6,0;              G0000003
     100       1       1       1                   0                  0000000D0000001
     100                       1                                      D0000002
     110       2       1       1                                      0000000D0000003
     110                       1                                      D0000004
     110       3       1       1                                      0000000D0000005
     110                       1                                      D0000006
     110       4       1       1                                      0000000D0000007
     110                       1                                      D0000008
     212       5       1       1                                      0001010D0000009
     212               256     1                                      D0000010
     106       6       1                                              0001010D0000011
     106               256     1      40                              D0000012
     106       7       1                                              0001010D0000013
     106               256     1      40                              D0000014
     214       8       1       1                                      0001010D0000015
     214               256     1       3                              D0000016
     214       9       1       1                                      0001010D0000017
     214               256     1       3                              D0000018
     216      10       1       1                   0                  0000010D0000019
     216                       1                                      D0000020
     212      11       1       1                                      0001010D0000021
     212               256     2                                      D0000022
     106      13       1                                              0001010D0000023
     106               256     1      40                              D0000024
     106      14       1                                              0001010D0000025
     106               256     1      40                              D0000026
     214      15       1       1                                      0001010D0000027
     214               256     2       3                              D0000028
     214      17       1       1                                      0001010D0000029
     214               256     2       3                              D0000030
     216      19       1       1                   0                  0000010D0000031
     216                       1                                      D0000032
     212      20       1       1                                      0001010D0000033
     212               256     2                                      D0000034
     214      22       1       1                                      0001010D0000035
     214               256     2       3                              D0000036
     214      24       1       1                                      0001010D0000037
     214               256     2       3                              D0000038
     206      26       1       1                   0                  0000010D0000039
     206                       1                                      D0000040
     110      27       1       1                                      0000000D0000041
```

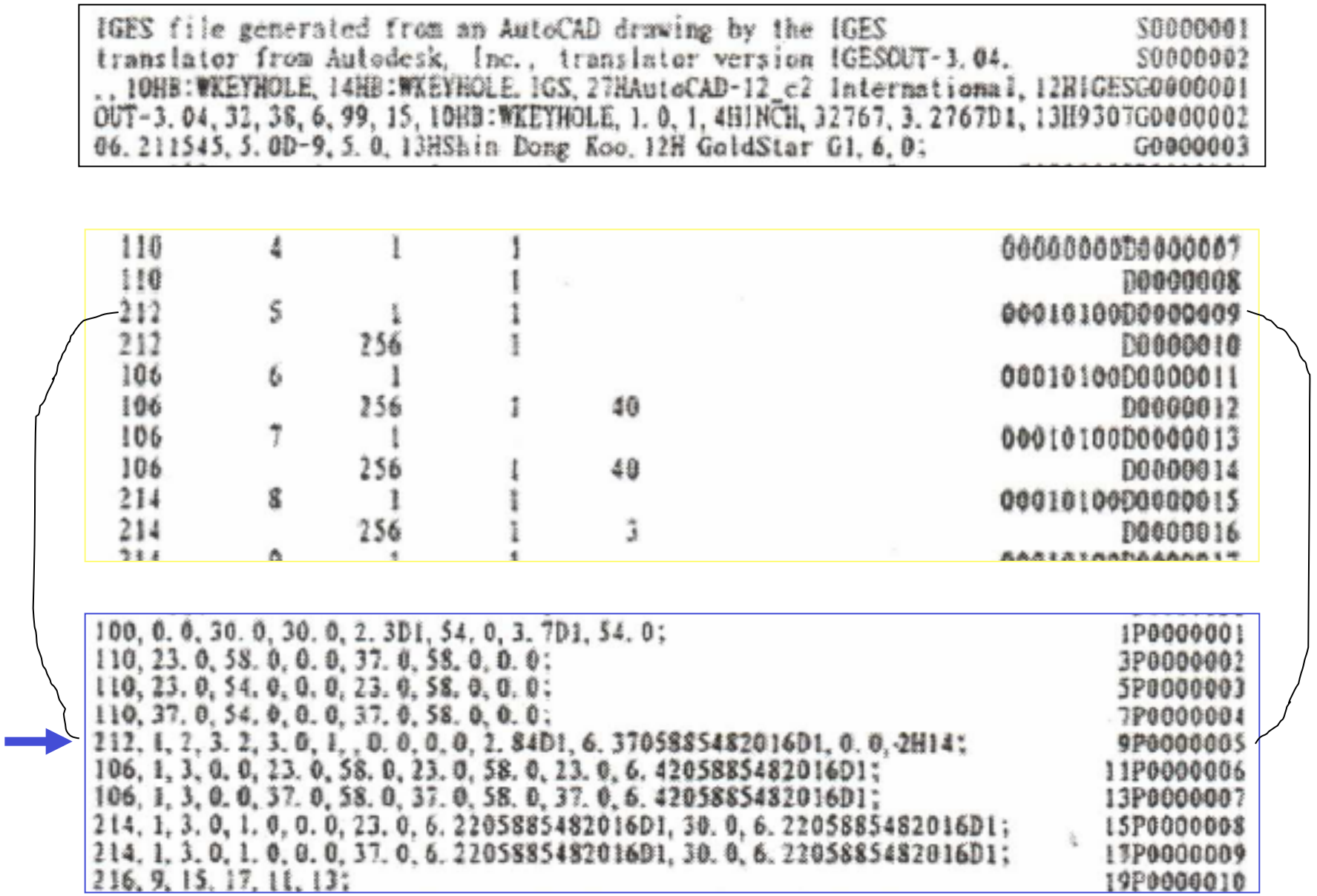
Directory Entry

An Example IGES File for the 2D Keyed Hole.




```
     110                       1                                      D0000042
     110      28       1       1                                      0000000D0000043
     110                       1                                      D0000044
     110      29       1       1                                      0000000D0000045
     110                       1                                      D0000046
     110      30       1       1                                      0000000D0000047
     110                       1                                      D0000048
     110      31       1       1                                      0000000D0000049
     110                       1                                      D0000050
     110      32       1       1                                      0000000D0000051
     110                       1                                      D0000052
100,0.0,30.0,30.0,2.3D1,54.0,3.7D1,54.0;                              1P0000001
110,23.0,58.0,0.0,37.0,58.0,0.0;                                      3P0000002
110,23.0,54.0,0.0,23.0,58.0,0.0;                                      5P0000003
110,37.0,54.0,0.0,37.0,58.0,0.0;                                      7P0000004
212,1,2,3.2,3.0,1,,0.0,0.0,2.84D1,6.3705885482016D1,0.0,2H14;         9P0000005
106,1,3,0.0,23.0,58.0,23.0,58.0,23.0,6.4205885482016D1;               11P0000006
106,1,3,0.0,37.0,58.0,37.0,58.0,37.0,6.4205885482016D1;               13P0000007
214,1,3.0,1.0,0.0,23.0,6.2205885482016D1,30.0,6.2205885482016D1;      15P0000008
214,1,3.0,1.0,0.0,37.0,6.2205885482016D1,30.0,6.2205885482016D1;      17P0000009
216,9,15,17,11,13;                                                    19P0000010
212,1,2,4.0,3.0,1,,1.5707963267949D0,0.0,6.5399660145317D1,           21P0000011
2.95D1,0.0,2H53;                                                      21P0000012
106,1,3,0.0,37.0,58.0,37.0,58.0,6.8899660145317D1,58.0;               23P0000013
106,1,3,0.0,30.0,5.0,30.0,5.0,6.8899660145317D1,5.0;                  25P0000014
214,1,3.0,1.0,0.0,6.6899660145317D1,58.0,6.6899660145317D1,           27P0000015
3.15D1;                                                               27P0000016
214,1,3.0,1.0,0.0,6.6899660145317D1,5.0,6.6899660145317D1,            29P0000017
3.15D1;                                                               29P0000018
216,21,27,29,23,25;                                                   31P0000019
212,1,5,6.0,3.0,1,,4.8571836262035D-1,0.0,-3.4208387606424D0,         33P0000020
1.4053290730212D1,0.0,5H%%c50;                                        33P0000021
214,2,3.0,1.0,0.0,7.8915046446839D0,1.8328960870709D1,3.0D1,          35P0000022
3.0D1,-2.7205731258678D0,1.2726781088893D1;                           35P0000023
214,1,3.0,1.0,0.0,5.2108495355316D1,4.1671093912910D1,3.0D1,          37P0000024
3.0D1;                                                                37P0000025
206,33,35,37,3.0D1,3.0D1;                                             39P0000026
110,2.8D1,30.0,0.0,3.2D1,30.0,0.0;                                    41P0000027
110,3.0D1,28.0,0.0,3.0D1,32.0,0.0;                                    43P0000028
110,2.6D1,30.0,0.0,3.0,30.0,0.0;                                      45P0000029
110,34.0,30.0,0.0,57.0,30.0,0.0;                                      47P0000030
110,3.0D1,26.0,0.0,3.0D1,3.0,0.0;                                     49P0000031
110,3.0D1,34.0,0.0,3.0D1,57.0,0.0;                                    51P0000032
S0000002G0000004D0000052P0000032                                      T0000001
```

Parameter Data



```
IGES file generated from an AutoCAD drawing by the IGES                    S0000001
translator from Autodesk, Inc., translator version IGESOUT-3.04.           S0000002
,,10HB:WKEYHOLE,14HB:WKEYHOLE.IGS,27HAutoCAD-12_c2 International,12HIGESG0000001
OUT-3.04,32,38,6,99,15,10HB:WKEYHOLE,1.0,1,4HINCH,32767,3.2767D1,13H930TG0000002
06.211545,5.0D-9,5.0,13HShin Dong Koo,12H GoldStar G1,6,0;                 G0000003
```

```
110       4       1       1                                    00000000D0000007
110                       1                                            D0000008
212       5       1       1                                    00010100D0000009
212               256     1                                            D0000010
106       6       1                                            00010100D0000011
106               256     1       40                                   D0000012
106       7       1                                            00010100D0000013
106               256     1       40                                   D0000014
214       8       1       1                                    00010100D0000015
214               256     1        3                                   D0000016
```

```
100,0.0,30.0,30.0,2.3D1,54.0,3.7D1,54.0;                                   1P0000001
110,23.0,58.0,0.0,37.0,58.0,0.0;                                           3P0000002
110,23.0,54.0,0.0,23.0,58.0,0.0;                                           5P0000003
110,37.0,54.0,0.0,37.0,58.0,0.0;                                           7P0000004
212,1,2,3.2,3.0,1,,0.0,0.0,2.84D1,6.3705885482016D1,0.0,2H14;              9P0000005
106,1,3,0.0,23.0,58.0,23.0,58.0,23.0,6.4205885482016D1;                   11P0000006
106,1,3,0.0,37.0,58.0,37.0,58.0,37.0,6.4205885482016D1;                   13P0000007
214,1,3.0,1.0,0.0,23.0,6.2205885482016D1,30.0,6.2205885482016D1;          15P0000008
214,1,3.0,1.0,0.0,37.0,6.2205885482016D1,30.0,6.2205885482016D1;          17P0000009
216,9,15,17,11,13;                                                        19P0000010
```

# What about the Elements You Import?

To make sure the elements you need to handle in your session are those you expected, here is a list presenting the IGES data supported when imported into a CATDrawing document:

| Element type | Element number in IGES format |
|---|---|
| circular pattern | 100 |
| composite curve | 102 |
| conic arc | 104 |
| copious data | 106 |
| line | 110 |
| parametric spline curve | 112 |
| point | 116 |
| transformation matrix | 124 |
| rational B-spline curve | 126 |
| offset curve | 130 |
| angular dimension | 202 |
| arc length dimension | 204 |
| diameter dimension | 206 |
| flag note | 208 |
| general label | 210 |
| general note | 212 |
| leader | 214 |
| linear dimension | 216 |
| point dimension | 220 |
| radius dimension | 222 |
| general symbol | 228 |
| sectioned area | 230 |
| subfigure definition (detail) | 308 |
| associativity instance (group) | 402 |
| drawing | 404 |
| properties | 406 |
| single subfigure instance (ditto) | 408 |
| view | 410 |

# DRAWING INTERCHANGE FORMAT (**DXF**)

Drawing interchange format (DXF) files were originally developed to give users flexibility in managing data and translating AutoCAD' drawings into file formats that could be read and used by other CAD/CAM/CAE systems.

Because of the popularity of AutoCAD, DXF became the de facto standard of interchanging CAD drawing files for almost all CAD/CAM/CAE systems. In fact, almost every newly introduced CAD/CAM/CAE system tends to provide translators to and from the DXF file.

A DXF file is an ASCII text file and consists of five sections:

- **Header** - describes the AutoCAD drawing environment that existed when the DXF file was created.
- **Table** - contains information about line types, layers, text styles, and views that may have been defined in the drawing.
- **Block** - contains a list of graphic entities that are defined as a group.
- **Entity** - immediately follows the Block section, and serves as the main part of the DXF file, with all entities of the drawing described in it.
- **Terminate** - indicates the end of the file.

background

content

data

Similar to that of the IGES files, the repertoire of the entities used in DXF files has been expanded with the introduction of the newer versions of AutoCAD.

A DXF file created by a higher version of AutoCAD cannot be read by other systems based on a lower version of DXF.

## Limitations of **IGES** and **DXF**

The IGES files and DXF files were developed to exchange product definition data instead of product data. By product data we mean the data relevant to the entire life cycle of a product (e.g., design, manufacturing, quality assurance, testing, and support).

Even though the specification of the IGES or DXF file has been broadened to encompass some of these product data, the data carried by those files are inherently insufficient to be the product data supporting the entire life cycle.

# PDES (Product Data Exchange Standard)

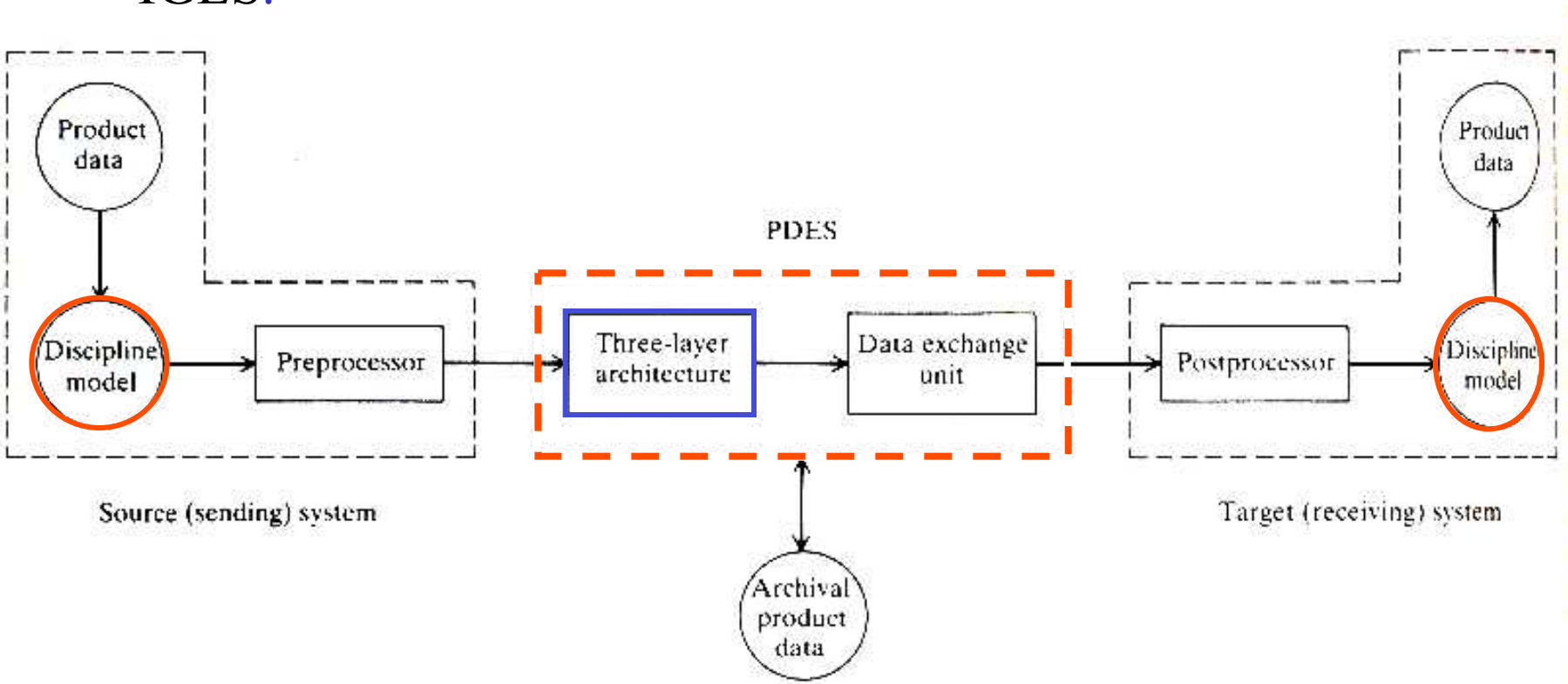
(then Product Data Exchange Using **STEP**)

- to support any industrial application such as mechanical, electric, plant design, and architecture and engineering construction

- to include all four types of data which is relevant to the entire life-cycle of a product: design, analysis, manufacturing, quality assurance, testing, support, etc.

# PDES

- PDES is a much more comprehensive and complex standard than IGES or any other predecessors
- The user interface is not as simple as "put IGES" and "get IGES."



# STEP (Standard for the Transfer and Exchange of Product Model Data)

- an **ISO standard** for the exchange of product data.
- The goal of this standard is to enable the exchange of a computerized product model with all its supporting types of data in a neutral format (all four types of data).

Introduction of **STEP**

Meanwhile, the International Organization for Standardization's (ISO's) Technical Committee TC184 (Industrial Automation Systems) and its subcommittee SC4 (External Representation of Product Model Data) were formed in July 1984 to establish a single worldwide standard for the exchange of product model data, STEP (Standard for the Exchange of Product model data).

Both PDES and STEP had the identical goal, so in June 1985 the IGES Steering Committee decided that PDES should represent U.S. interests in the STEP effort. As a result, the acronym PDES has been changed to stand for product data exchange using STEP, to emphasize the intention that **PDES and STEP be identical.**

**PDES** (Product Data Exchange Standard) reinterpreted as **Product Data Exchange Using STEP**

## APPLICATION PROTOCOLS AND ASSOCIATED ABSTRACT TEST SUITES

I 201 Explicit draughting (W)*
I 202 Associative draughting (C)
I 203 Configuration-controlled design (C)
C 204 Mechanical design using boundary rep (C)
C 205 Mechanical design using surface rep (W)
X 206 Mechanical design using wireframe (X)
E 207 Sheet metal die planning and design (C)
W 208 Life-cycle product change process (W)
C 209 Compos & metal struct, anal, & related dgn (W)
C 210 Electronic P-C assy: product-design data (W)

X 211 Electronic P-C assy: test, diag, & rem anuf (W)
C 212 Electrotechnical design and installation (W)
E 213 Num contr (NC) process plans for mach'd parts (W)
C 214 Core data for automotive mech dgn processes (W)
W 215 Ship arrangements (W)
W 216 Ship moulded forms (W)
W 217 Ship piping (W)
W 218 Ship structures (W)
X 219 Dimension inspection (X)
O 220 Printed-circuit assemblies: mfg planning (O)

C 221 Process plant functional data & its schem rep (W)
W 222 Design-manuf for composite structures (W)
W 223 Exc of dgn & mfg product info for cast parts (W)
E 224 Mech parts def for p. plg using mach'n'g feat (W)
E 225 Structural bldg elem using explicit shape rep (W)

W 226 Ship's mechanical systems (W)
E 227 Plant spatial configuration (W)
O 228 Building services: HVAC (O)
W 229 Forged parts (W)
W 230 Building structural frame: steelwork (W)

W 231 Process-engineering data (W)
W 232 Technical data packaging: core info & exch (W)
O Neutral optical-data-interchange format (O)
O Product life-cycle support—NATO (O)
O SGML and industrial data (O)

## IMPLEMENTATION METHODS

| | |
|---|---|
| I 21 Clear text encoding of ex ch str. | C 24 Late C (binding for #22) |
| E 22 Standard data access interface | X 25 Late FORTRAN |
| E 23 Early C++ (binding for #22) | E 26 IDL (binding for #22) |

## CONFORMANCE TESTING METHODOLOGY FRAMEWORK

I 31 General concepts
E 32 Requirements on testing labs and clients
X 33 Abstract test suites
C 34 Abstract test methods for Part 21 impl.
W 35 Abstract test methods for Part 22 impl. (Approved for new scope)

## DESCRIPTION METHODS

I 1 Overview and fund. principles ( Amend. 1 = 0 )
I 11 EXPRESS lang ref man. ( Ed 2 = W )
X 12 EXPRESS I lang ref man ( Type 2 tech report = W )

## INTEGRATED-INFORMATION RESOURCES

### INTEGRATED-APPLICATION RESOURCES

I 101 Draughting
X 102 Ship structures
X 103 E/E connectivity
C 104 Finite element analysis
I 105 Kinematics
W 106 Building core model
A 107 Engineering anal core

### INTEGRATED-GENERIC RESOURCES

I 41 Fund of prdct descr & spt (ed2 = A)
I 42 Geom & topol rep (Amd1 = W)
I 43 Repres specialization (ed2 = A)
I 44 Product struct config (ed2 = A)
F 45 Materials
I 46 Visual presentation
F 47 Tolerances
X 48 Form features
F 49 Process structure & properties

### APLLICATION-INTERPRETED CONSTRUCTS

C 501 Edge-based wireframe
C 502 Shell-based wireframe
C 503 Geom-bounded 2D wireframe
C 504 Draughting annotation
C 505 Drawing structure & admin
C 506 Draughting elements
C 507 Geom-bounded surface
C 508 Non-manifold surface
C 509 Manifold surface
C 510 Geom-bounded wireframe
C 511 Topol-bounded surface
C 512 Faceted B-representation
C 513 Elementary B-rep
C 514 Advanced B-rep
C 515 Constructive solid geometry
X 516 Mechanical-design context
C 517 Mech-design geom presentation
C 518 Mech-design shaded presentation
C 519 Geometric tolerances
C 520 Assoc draughting elements

# ANSYS Workbench Environment

## CAD Associativity and Bi-Directional Associativity of ANSYS Products

The ANSYS Workbench Environment uses a unique Plug-In architecture to maintain associativity with the CAD systems for solid and surface models, allowing you to make design changes to your CAD model without having to reapply any of the loads and or supports. Bi-directional associativity in Workbench Environment advances your productivity one step further by providing control of your key CAD model parameter in the Workbench Environment parameter manager. With feature, you can create simulations with multiple CAD models and Workbench Environment will automatically update the geometry for each simulation situation.

for better one-to-one data exchange

Below are a list supported CAD systems and file types:

**Associative**

- Unigraphics
- Pro/ENGINEER
- Autodesk Inventor
- Autodesk MDT
- Solid Edge
- SolidWorks

**Non-Associative**

- CATIA
- SAT
- Parasolid

IDEAS

If your company uses multiple CAD systems, multiple geometry interfaces may be used with your Workbench products. This way, when working in a multi-CAD environment, Workbench maintains the same operational look, feel and capability. You can then minimize your training effort and establish common simulation methods that will permit confident results.

# Possible Information Loss

- Like any language translation, there is always information loss during the product data information translation
- Examples
  - A design tolerance is captured as a text string placed on a drawing, its meaning, as well as its numerical value, are lost.
  - Circular cylinders (a hole) is represented by NURBS; milling vs. drilling
  - Offset surfaces; the offset info is lost.
- Integrated CAD/CAE/CAM packages

# Quick Questions

- What is IGES, PDES, and STEP?
- What are the limitations of IGES?
- What need to be transferred?
- Why can’t the information be completed exchanged between CAD tools?